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EXPERT – SYSTEM APPROACH FOR SELECTING MECHANIZED IRRIGATION SYSTEMS FOR DIFFERENT SITUATIONS

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ABSTRACT

The objective of this investigation is to help in selecting the appropriate irrigation system, in certain situations.

Systems under investigation included: (1) surface-flood, (2) common sprinkler (3) center-pivot sprinkler system, (4), common drip, and (5) solar-powered drip.

Evaluation of systems for selection depended on farm resources (soil, water, crop, labor, energy, and cost). Results of expert system (ES) approach were validated through consultation with domain experts and references. Each irrigation system was given a score for every resource item. The highest summation for any system indicates its suitability for the set of conditions imposed.

Three trial cases were put under validation:

(1) Nile delta (old lands), (2) Nubaria (new lands), and (3) Toshki (Large Reclamation project).

Results corroborated that for the delta area (with field crops) surface flood irrigation was the most appropriate, with a score weight of 9.76, which is about 40 % above the average of all the choices. On the other hand, for the Nubaria case (orchards), the most appropriate system proved to be the dripping (9.25 score) 15% above the average. In large projects (Toshki, forage and cereal crops) the pivot and sprinklers showed feasibility (9.23 Score) 8 % above average. The solar-drip system gains no ground at present, probably due to high initial cost, but can be used in remote areas or when hardware becomes less expensive.

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In conclusion, the ES proposed is validated different cases, including extreme representative situations.

Key words:

Expert system, irrigation systems, surface-flood irrigation, drip irrigation, sprinkler irrigation, centre-pivot sprinkling; solar-powered drip irrigation.

I. INTRODUCTION

Selecting an irrigation system requires a database of the available resources. Evaluation of these resources yields the potentials and constraints which affect the selection. Distinctive choices to select from include spinkler and drip systems. However, there are many subgroups among these systems of specific interest including solar-powered drip and center-pivot spinkler systems (Awady et al., 2001 a, b).

For the process of selection between different irrigation systems, Chen et al. (1976), Slomon (1988), and Thompson et al. (1990) listed a few resource qualifiers including three main groups: (a) physical: soil, crop, water, climate, cultural practices, energy available, etc.., (b) economical: capital requirement, running cost, efficiency, etc.., and (c) social considerations: labor, etc..

Expert system (ES) is used for selection among systems, since it mimics solving problems by a human expert (Hassan and Sharaf, 1997). The advantage of ES lies in integrating objectives and databases to give the solution. Awady et al. (1997) used ES to incroporate environmentail qualifiers (Soil, crop, practices etc..) to recommend machinery chocies, manifested by weights of confidence. Results were validated by consultation with domain experts and knowlodge available from literature and pertinent experimentation.

Objectives of this paper include an approach for selecting irrigation systems appropriate for a set of quilifing resource-conditions, based on ES. Some preliminary experiments were run to evaluate particular characteristics, especially with solar-powered drip and center pivot systems, Hegazi (2000). However a second-round rules and new decision table were prepared to reflect later modifications, and to accommodate validation of important representative cases: Nile-Delta old lands (field crops), Toshki (large project, cereals and forage crops), and Nubaria (reclaimed land, horticultural crops).

II. MATERIAL AND METHODS

Experimients were conducted at the "Nuclear Research Center, Inshas, Atomic Energy Authority of Egypt" to collect data usable in comparing between systems (Hegazi, 2000). They namely dealt with solar-powered drip and small center-pivot irrigation systems (90-m boom). Resualting database contained knowledge of the uniformity of water emission and moisture distribution from the systems.

Data for other sites or situations were taken from literature and general experience.

2a: Procedure for the selection of the suitable irrigation systems

The ES developed for selecting the suitable irrigation method in different situations comprise the use of available database from knowledge-base resources and rules of judgement outlined by domain experts in the fields of irrigation systems and soil-water selections.

As Awady et al. (1997) iterated, the first step in ES development is the identification of the qualifying variables (conditions) involved. Important variables are conceptualized to structure the problem by domain experts. The procedure results in a comprehensive view of the irrigation-system selection.

Decision tables were prepared for the qualifiers leading to choices of irrigation systems. Each case had scores of confidence for each irrigation system, which indicate suitability to the circumstances imposed.

Further development of the selection system can involve transforming all the knowledge base to an ES-shell such as "EXYSP" software, used elsewhere (Awady et al., 1997).

2b- Irrigation-syatem choices and qualifiers

Pelevant choices were taken as: (1) flood, (2) common spirnkler, (3) pivot sprinklers, (4) common drip, and (5) solar-powered drip. Data were taken from experience on flood, common sprinklers, and dripping. Some other data on solar-powered drip and center-pivot systems are taken from former experiments (Hegazi, 2000) and (Awady et al., 2001 a, b). The comparison between the different systems depended upon qualifier factors. They included:

(1) Water factors: Availability, salinity, contamination causing clogging.

(2) Soil factors: Texture, water-table, salinity, surface topography, calcium content, surface erosion, and land shortage.

(3) Crop: Consumptive-use of water (CUW), and weeds infestation.

(4) Climate: Temperature, humidity, and wind.

(5) Uniformity of water distribution (DU): Giving more credit to drip (0.84) compared with 0.64 for center-pivot sprinkler (Awady et al., 2001 a, b), and 0.78 for spinkler systems (Arnaout, 1997).

(6) Energy requirement: Pivot systems require the highest energy (due to high pressure 3.5-5.0 bar), while flood systems require the least. In the decision table, the highest credit (unity) concerning energy consumption was thus given to flood irrigation, and the lowest (zero) was given to pivot system.

(7) Technical appropriateness (TA): The plot sizes are taken as indicator to the availability of tec. Support. i-e: in small plots, pivot-system is given (zero score), with higher scores for other systems.

(8) Cost: The most cost intensive is the fixed-sprinkler system (zero score), while flooding requires least cost, thus having advantage (0.75 score). It is given the highest score (1.00) in large area (Toshki).

Virtual scores were allotted to different choices according to different qualifiers. Their assumption was based on experience and judgement of the authors and domain experiments. Some were based on autcome of experiments (such as uniformity of water distribution., Hegazi, 2000), while others were extracted from literature, such as energy requirement (Abd El Moksoud et al., 1994).

Due consultations were held with domain experts to determine the qualifiers and test the outcome of case studies. Irregular outcomes were adjusted via values embedded in different rules. Effects were remarked on targeted and correlated choieces. This procedure was iterated until obtaining satisfactory results.

The domain experts included, in addition to the authors, two staff members from the soil and water Res. Dept., Nuclear Res. Centre, Atomic-Energy Authority.

2c: Validation of cases and remarks

Study cases were exposed to consultation with domain experts, for validation of results. Each irrigation choice was weighed under each suggested case. The manipulation of the decision table was done manually, although could be plugged into an ES-shell for computer aid.

2d: Case studies

Three representation sites were examined, to represent extreme cases in Egyptian irrigation situations: old lands, new lands, and large projects.

2e: The decision table

Table 1 shows the system choices, and qualifier condition. This table is modified from Hegazi (2000) to deal more accurately with the general scope of comparison, and validate with the extreme cases.

III. RESULTS AND DISCUSSION

Following are selection tables, derived from the dicision table, for the particular cases under study. For each case, a brief description of its data is given above the table. Final result scores are extracted below tables.

Table 1: Decision table:

Qualifier	Irrigation Method				
	Flood	Sprink.	C- pivot	Drip	Sol-drip
1-Water abundance					
a- Abundant	1.00	0.50	0.50	-	-
b- Scarce	0.00	0.50	0.50	1.00	1.00
2-Water salinity					
a- < 800 ppm	0.75	0.50	0.50	0.50	0.50
b- > 800 ppm	1.00	0.00	0.00	0.25	0.25
3-Clog resist.	1.00	0.75	0.75	0.00	0.25
4-Soil type					
a- Light soil	0.25	0.50	0.50	0.75	0.80
b- Heavy soil	0.75	0.50	0.50	0.50	0.50
5-High W. table	0.00	0.75	0.75	1.00	1.00
6- Saline soil	1.00	0.00	0.00	0.00	0.00
7- Calcareous soil	0.00	0.75	0.75	0.75	0.75
8- Weed infest.	0.00	0.00	0.00	1.00	1.00
9- Soil erosion	0.00	1.00	1.00	0.50	0.50
10-Tech. approp.					
a-Small plots	0.50	0.75	0.00	0.75	0.75
b-Large plots	0.50	0.75	1.00	0.75	0.25
11- Unlevel land	0.00	1.00	1.00	0.50	0.25
12- Crop					
a- Field crops	1.00	1.00	1.00	0.50	0.00
b- Orchard trees	1.00	0.50	0.00	1.00	0.50
c- Vegetables	1.00	1.00	0.50	0.25	0.00
d- Greenhouses	0.00	1.00	0.00	1.00	1.00
13-Climate aridity	0.20	0.50	0.50	0.75	1.00
14-Applic. Uniformly	0.76*	0.78*	0.80#	0.80#	0.85#
15-Labor					
a- Available	1.00	0.50	0.00	0.50	0.25
b- Scarce	0.00	0.50	1.00	0.50	0.75
16- Energy savg.	1.00	0.25	0.00	0.50	1.00
17- Initial cost saving	1.00	0.25	0.10	0.20	0.00

* Arnaout (1997), # Hegazi (2000).

3a: Nile –Delta region (field-crop rotation)

Area eventually comprises old lands with small plots. Nile water is available, but contaminated with clog ants. Soil is heavy, amenable to salinity and alkalinity; with high water table. Topography is level. Crops are variable, possibly with rice in a rotation. Climate is semi-arid. Labor is available with limited tec. background. Network elec. is available with diesel-power supplement.

Qualifiers	Irrigation Choices				
	Flood	Sprink.	C- pivot	Drip	Sol-drip
1a- Water, abundant	1.00	0.50	0.50	-	-
2a- Water salin < 800 ppm	0.75	0.50	0.50	0.50	0.50
3- Clog resist.	1.00	0.75	0.75	0.00	0.25
4- Soil type: Heavy	0.75	0.50	0.50	0.50	0.50
5- High W- table	0.00	0.75	0.75	1.00	1.00
6- Saline soil	1.00	0.00	0.00	0.00	0.00
8- Weed infest.	0.00	0.00	0.00	1.00	1.00
10- Tech. approp: small	0.50	0.75	0.00	0.75	0.75
12- Crop: field C., rice	1.00	1.00	1.00	0.50	0.00
14- App. Uniformity	0.76	0.78	0.63	0.80	0.85
15a- Labor avail.	1.00	0.50	0.00	0.50	0.25
16- Energy savg.	1.00	0.25	0.00	0.50	1.00
17- Init-cost savg.	1.00	0.25	0.10	0.20	0.00
Resulting scores	9.76	6.53	4.73	6.25	6.10

3b- Nubaria area (Orchard area)

The area is newly reclaimed. Water comes from "El Nasr Canal ترعة النصر". It carries a heavy load of polluting clog-ants. Regulations restrict water application to 5000 m^3/fed/yr. Soil is dominantly light and calcareous. Surface is moderately level. Orchard dominate the area. Climate is mild. Labor is scarce and unskilled. Elec. network covers the area: with supplemental diesel power.

Qualifiers	Irrigation Choices				
	Flood	Sprink.	C- pivot	Drip	Sol-drip
1b- Water, shortage savg.	0.00	0.50	0.50	1.00	1.00
2a- W. slain< 800 ppm	0.75	0.50	0.50	0.50	0.50
3- Clog. resist.	1.00	0.75	0.75	0.00	0.25
4a- light soil	0.25	0.50	0.50	0.75	0.80
5- High W- table	0.00	0.75	0.75	1.00	1.00
6- Saline soil	1.00	0.00	0.00	0.00	0.00
7- Calcareous soil	0.00	0.75	0.75	0.75	0.75
8- Weed infest.	0.00	0.00	0.00	1.00	1.00
9- Soil erosion	0.00	1.00	1.00	0.50	0.50
10b- Tech. approp.: large	0.50	0.75	1.00	0.75	0.25
12- Crop: orchards trees	1.00	0.50	0.00	1.00	0.50
14- Applic. uniformity	0.76	0.78	0.63	0.80	0.85
15b- Labor: scarce	0.00	0.50	1.00	0.50	0.75
16- Energy savg.	1.00	0.25	0.00	0.50	1.00
17- Init-cost savg.	1.00	0.25	0.10	0.20	0.00
Resulting scores	7.26	7.78	7.48	9.25	9.15

3c: Toshki (Large project, cereals and forage area)

Area description: Vast areas, arid conditions, water is expensive for pumping from wells or Dam Reservoir, land levelling is not sure, crops, area considered cereal and forage, labor is scarce, tech. support available, and electricity is available.

Qualifiers	Irrigation Choices				
	Flood	Sprin.	C. pivot	Drip	Sol-drip
1b- Lifted water	0.00	0.50	0.50	1.00	1.00
2a- Water slain 800 ppm	0.75	0.50	0.50	0.50	0.50
3- Clog. resist.	1.00	0.75	0.75	0.00	0.25
4a- light soil	0.25	0.50	0.50	0.75	0.80
7- Calcareous soil	0.00	0.75	0.75	0.75	0.75
8- Weed infest.	0.00	0.00	0.00	1.00	1.00
9- Soil erosion	0.00	1.00	1.00	0.50	0.50
10b- Tech. large plots	0.50	0.75	1.00	0.75	0.25
11-Unlevel land	0.00	1.00	1.00	0.50	0.25
12a- Field crops	1.00	1.00	1.00	0.50	0.00
13- Climate aridity	0.20	0.50	0.50	0.75	1.00
14- Applic. uniformity	0.76	0.78	0.63	0.80	0.85
15b- Labor scarce	0.00	0.50	1.00	0.50	0.75
16- Energy savg.	1.00	0.25	0.00	0.50	1.00
17- Init. cost	1.00	0.25	0.10	0.20	0.00
Resulting scores	6.46	9.03	9.23	9.00	8.90

IV. CONCLUSION

The validation of cases showed that the proposed decision table can meet different situations with reasonable results.

Fig.1. presents the resulting choices for the different situations under examination. Eminently in the case of old lands, surface flood irrigation was evaluated highly (9.76) which is about 40 % above the average of all the choices. For evident reasons, the pivot system was lowest down the list (4.73). the rest of methods were near in score (between 6.10 for solar drip and 6.53 for sprinkling).

From the same figure, the selection tables produced the common drip systems as best for horticultural areas in new lands, (score 9.25, 15 % above the average), which conforms with the general practice. This is mainly due to limited water quota imposed in the area (5000 m^3/fed/y), due to moderate surface unevenness, and light soil. Other irrigation systems, different from dripping were close in scores, between 7.26 and 7.78.

In large projects (Toshki, cereals and forage areas) the results are logical in selecting the pivot system (9.23 score, 8 % above average). With marginal advantages over other systems, discluding flooding (6.46). Center pivot, in such vast tracts and field crops is eminent because it humidifies environment and protects light soil against wind erosion, tolerates some land unevenness, with more comfortable management, where labor is scarce and technology is at hand.

In conclusion the validation cases proved the integrity of the ES constructed here, which gave the best practice in judging extreme cases, and anticipated variants in between.

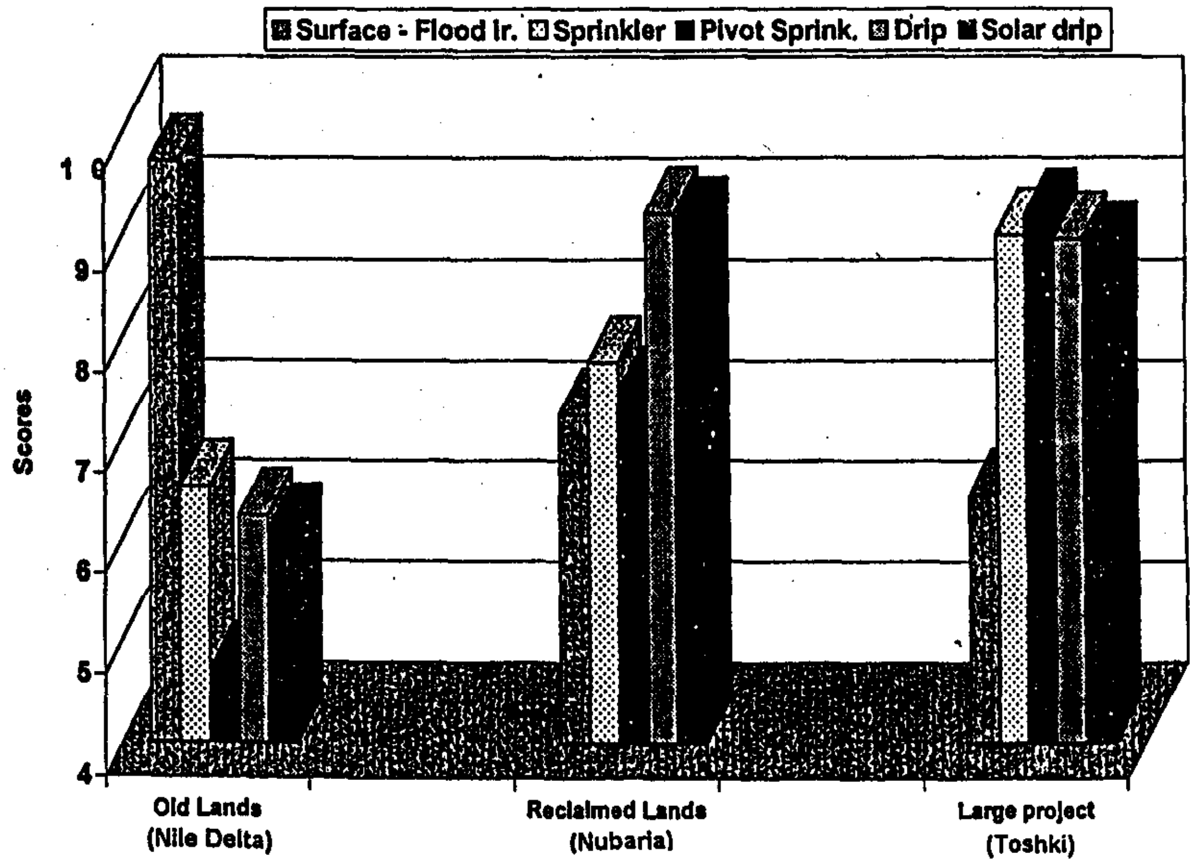

Fig. 1: Scores of different irrigation choices for representative situations.

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أسلوب نظام خبرة لاختيار نظم الري المميكن لمختلف الظروف

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ملخص البحث

يهدف هذا البحث إلي المعاونة في اختيار نظم الري المناسبة لظروف معينة.

وتشمل نظم الري تحت الدراسة: (١) الغمر السطحي ، (٢) الري بالرش المعتاد ، (٣) نظام الري بالرش المحوري ، (٤) الري بالتنقيط المعتاد ، (٥) الري بالتنقيط باستخدام الطاقة الشمسية.

وقد اعتمد تقييم نظم الري علي المقومات المزرعية (التربة ، والمياه ، والمحصول ، والعمالة ، والطاقة ، والتكاليف). وتم إثبات صحة نتائج اسلوب نظام الخبرة باستشارة خبراء المجال والرجوع إلي المراجع. وقد أعطي كل نظام ري درجة لكل عنصر من عناصر التقييم. ويدل أعلى مجموع درجات لأي نظام على ملائمته لمجموعة ظروف حالة الدراسة.

أخذت ثلاث حالات دراسة متباينة لإثبات صحة نظام الخبرة: (١) مناطق دلتا نهر النيل (أراضي قديمة) ، (٢) النوبارية (أراضي جديدة) ، (٣) توشيكي (مشاريع الإستصلاح الكبرى).

وقد أوضحت نتائج نظام الخبرة منطقية اختيار نظام الري السطحي بالغمر التي تزرع محاصيل حقلية بدرجة ٩,٧٢ والتي تزيد بنحو ٤٠ % عن متوسط درجات كافة الخيارات. وعلي الجانب الآخر ، كان الري بالتنقيط أنسب نظام لمنطقة النوبارية التي تزرع أشجار بساتين (٩,٢٥ درجة) تزيد ١٥ % عن المتوسط. أما للمشاريع الكبرى (توشيكي ، مزارع أعلاف وحبوب) فقد أظهرت نظم الري بالرش جدواها (٩,٢٣ درجة) بزيادة ٨ %عن المتوسط. ولم يظهر نظام الري بالتنقيط باستخدام الطاقة الشمسية جدوى في الظروف الحالية ، وذلك نظراً لارتفاع رأس المال اللازم له ، ولكن يمكن استخدمه في المناطق النائية أو عندما تنخفض أسعار المعدات.

وفي الخلاصة فقد أثبت نظام الخبرة المقدم صحته في الأحوال المختلفة ، بما في ذلك الحالات المختلفة الممثلة المتطرفة.

__كلمات مفتاحية:__

نظام الخبرة ، نظم الري ، الري السطحي بالغمر ، الري بالتنقيط ، الري بالرش ، الري بالرش المحوري ، الري بالتنقط بالطاقة الشمسية.

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علي الترتيب: أستاذ مساعد وأخصائي ، القسم الزراعي لبحوث الأراضي والمياه مركز البحوث النووية ، هيئة الطاقة الذرية ، القاهرة.